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DESIGN AND MANUFACTURING OF AN AMMUNITION HANDLING AND TRANSPORT SYSTEM

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ABSTRACT

The present paper describes in a systematic and organized way the design processing and system manufacturing of missiles handling and transport vehicle, according to the specific requirements of the Air Armament Squadron of Air Combat Command number five (5) by its acronym in Spanish CACOM 5. This research presentation is a part of the ground support team's development specializing in transporting processes and installation of weapons in military and defense aircraft. In the present work, the process of a designing and manufacturing system composed by a cargo vehicle and a missile handling vehicle that allows the aerial armament team, reduce transport and handling risks, as well as the personal injury or risk of the staff in charge of the installation process.. This research around the ground support system was built in order to meet the specific needs of the Colombian Air Force, specifically for the AH60L fleet.

KEYWORDS: Missile, Loader, Ammunition, Weapon, Rocket, Aircraft, Aerial missile, Aerial stores, Transporter & Truck Handling

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Original Article

INTRODUCTION

The task of handling weapons ammunition and explosives is, by nature, dangerous. Accidents occurring during these operations would be mortal and in the most of cases, could lead to injury the staff, destroy essential supplies, damage valuable equipment and property, and reduce the efficiency and the speed of handling operation. Most accidents could be avoidable provided the proper safety precautions are implemented. These accidents are caused due to carelessness or unfamiliarity with the use and limitations of the handling equipment, otherwise, laxness and failure to observe safety precautions.

Accidents caused by misuse of handling equipment can be prevented by a thorough understanding of equipment operation, its use and limitations [1].

The transport and handling of ammunition and weapons in the process of aircraft supply is one of the processes that requires the use of equipment with special characteristics, due to the great variety of components and configurations used in defense systems. Moreover, in the Colombian Air Force, the work team that is responsible for the loading of ammunition in combat aircraft is called Armament Weapons Support Equipment (AWSE). This

group comprises of three (3) categories - Armament Support Equipment (ASE) or Armament Handling Equipment (AHE), Weapons Support Equipment (WSE), and Logistics Support Equipment (LSE) [2]. Particularly, Armament Handling Equipment includes special tools used to support the aircraft in providing handling, movement, installation, configuration, arming, loading and unloading of air launched weapons, airborne armament systems, or weapon related components. Armament handling equipment includes bomb hoists, single hoist loading systems, weapon loaders, boresights, and special tools used to remove, replace, repair, test, assemble, or service aircraft bomb racks, missile launchers, installed machine guns, or gun pod units [2].

In the present case, a system composed of a transport vehicle and a handling vehicle has been developed in order to supply the transport and handling requirements of the missile manufacturer and the technical requirements of the CACOM 5. Both equipmentss are part of the Armament Handling Equipment and were designed and manufactured to fulfill specific functions. The transport vehicle was designed and built with a trailer configuration to be operated with a truck or tractor.

This vehicle has an independent suspension system in order to protect the armament and can only be mobilized outside the security zones of the platform where the aircraft is located.

On the other hand, the handling vehicle has been configured to and has the capacity to raise loads of up to two hundred (200) kg with a radius of action of one point Eight (1.8) meters. The system has been designed and manufactured for the following reasons:

- Rapid execution of your task when the aircraft to be loaded requires several successive missions in an adjusted time frame.
- Compliance with the highest possible safety standards, due to the nature of the loads handled.
- Ability to maneuver in areas of restricted space, since it is often necessary to move around places such as aircraft hangars, where the aircraft and maintenance equipment leave little space.

SYSTEM DESIGN METHODOLOGY AND MANUFACTURING

Design of the Ammunition Lifting Vehicle

Whereas a conventional engineering process begun with a design concept, in reverse engineering, a product is designed by capturing the shape of the real part in order to emulate and improve the original piece. The piece that had a freeform surface was usually developed through the reverse engineering process.

Acquiring the shape of a physical part is an essential process in reverse engineering. The quality of the reconstructed surface structure depends on the type and accuracy of measured data point, as well as the type of measuring device [3, 4, 5].

The process prior to the system design consisted in a components metrological scan in order to be manipulated and transported, as well, obtained the spaces dimensioning where the missiles are handled and located. For this purpose, a HANDY SCAN scanner with a volumetric precision of 0.0434 mm (2) was used. Figure 1 illustrated the real engineering part vs the scanned generated.

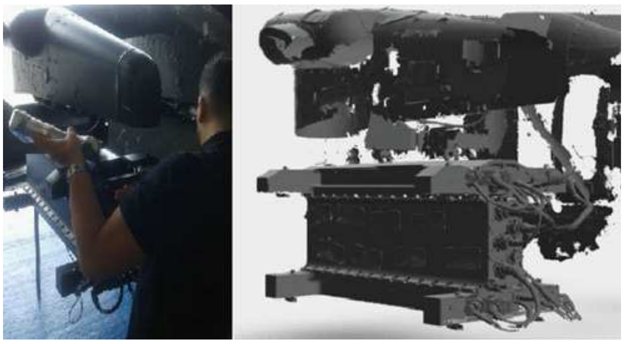

Figure 1: Dimensional Metrology of the Components. Own Elaboration.

According to the requirements, the methods and times study of the assembly process of missiles in the aircraft AH60, the sketches of the possible configurations of the equipment are made, which was validated with the aerial armament equipment of the CACOM-5 as is illustrated in figure 2. The design of engineering shapes, idea sketches were drawn at an early stage of design procedures, then, a 3D models was constructed as is showed in figure 2 [7].

Figure 2: Validation of Previous Designs of Aerial Armament Equipment. Own Elaboration.

After the design validation and approval, the CAD models of both systems were carried out in order to do a numerical validation by software (Finite Element Analysis-FEA) to find the deformations and stresses, which allowed defining criteria of design as materials, thicknesses, manufacturing processes, etc. Additional efforts were made to perfect the design of the chassis structures of both vehicles; as a support structure, it should be rigid enough to withstand the shock, twist, vibration and other stresses. [8]

The finite element analysis process - FEA (Finite Element Analysis - FEA), was carried out using modern meshing techniques of different mesh sizes and with the appropriate border restrictions. The results allowed predicting the static behavior of the metallic structures is showed in figure 3.

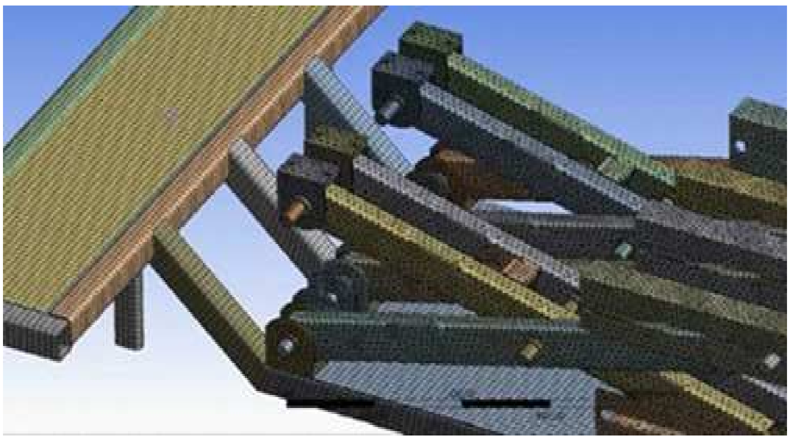

Figure 3: Meshing Process of the Lifting Vehicle. Own Elaboration.

During the Meshing process, 543,786 Nodes and 179, 230 elements were defined for the FEA. In addition, the load values were determined from the nominal weight values of the missiles.

The results of the simulation process can be seen in figure 4.

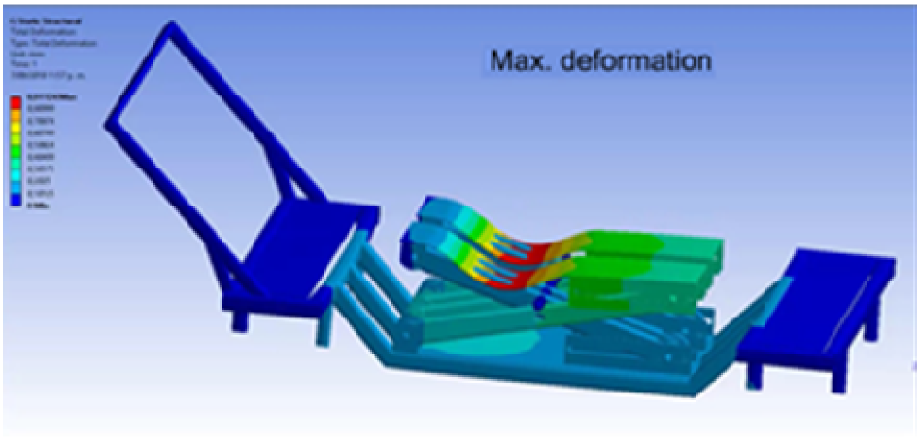

Figure 4: Simulation Process Results of Total Strain. Own Elaboration.

In the case handling vehicle structure simulation, the maximum effort calculated was 52.5 MPa (320 MPa being the average of the Fluency Effort of commercial steel), located at the junction points (boundary condition - welding) between the bodies.

The strain simulation, according to the load conditions and materials selected, places the maximum strain in the upper base of the SPIKE NLOS 5 missile support platform (Figure 4).

The strain result was 1mm. With the results and the validation of finite elements - FEA, the staff proceeds to generate the planes of manufacture and construction of the vehicle. Likewise, the schematic and technical diagrams of the electrohydraulic system were generated, according to the required quality requirement. The schematic and technical diagram of the electro hydraulic system is illustrated in figure 5.

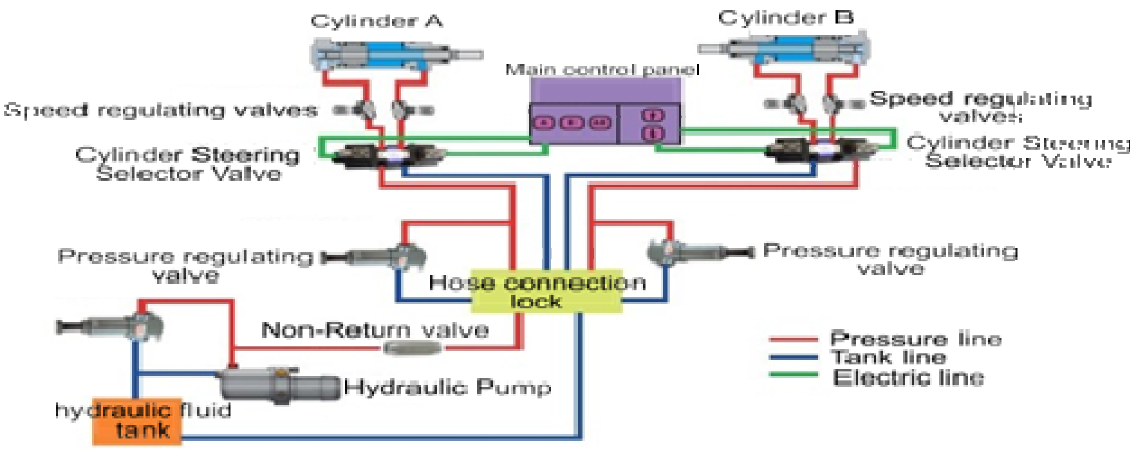

Figure 5: Schematic Diagram Electro hydraulic System for Lifting Vehicle. Own Elaboration.

Once the FEA simulations and the design sketch were made, the manufacturing process began with the construction of the frame and the integration with the electrohydraulic components according to specifications defined in the previous design phases. The detailed process is illustrated in the sequence of the photographic record in figure 6.

Figure 6: Manufacturing Frame. Own Elaboration.

In the scissors manufacturing process of the lifting system, system modifications were made from simple scissors to double scissors. This modification were made in order to minimize the risks of movement of the loaded platform, at the moment of achieving its maximum elevation with the missile on it; this phenomenon of mechanical hysteresis, is known as "whipping" and it is reduced manufacturing the double scissor, as is showed in figure 6.

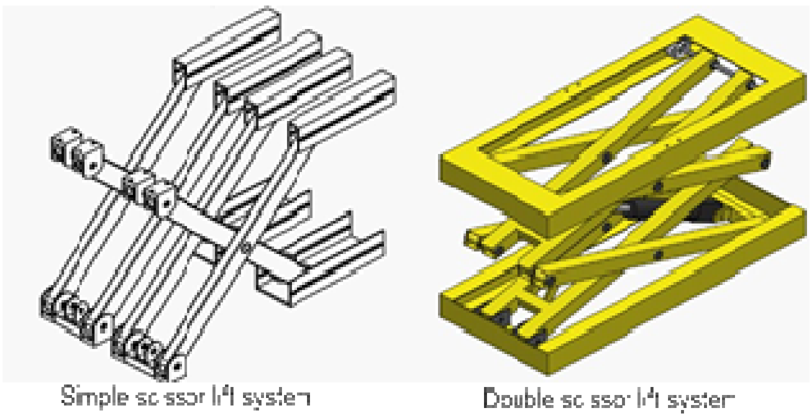

Figure 7: Single scissors Vs Double scissors system. Own elaboration.

Once the modification was applied to the scissor lift system, the distances of the hydraulic cylinders were adjusted, reducing the inertial load when the scissors operating were in deployment. This improvement in the inertial load on the cylinders increases the number of cycles to be carried out with an electrical load of the system, due to less force is needed when lifting the platforms, less hydraulic pressure is required from the pump and lower energy consumption in the batteries.

As the functional tests carried out, the personnel of the aerial armament team of the CACOM-5 verified the distances, weights and configuration of the vehicle. From this verification, recommendations were made in order to improve the distance of the frame, adjusting the supports and arrangement of the profiles of the base frame. These adjustments were made without modifying the functional electro- hydraulic system.

Once the electro hydraulic systems were set in a functional configuration, the electrical, hydraulic components and circuits were installed; the connections were verified and the possible risks prior to the components operation were

identified. Subsequently, the functional tests were performed with- out load, in order to verify the performance of the components.

Figure 8: Installation and Testing of Components and Systems. Own Elaboration.

The last step completed once the electrohydraulic system was development was applied an industrial coatings to in order to protect the metal of the structure and its components to ensure that the elements do not affect over time, as they remain subjected to adverse environmental conditions.

With the final assembly of the equipment, field performance tests were carried out in order to review their performance and verify how the equipment improves the operation and response conditions of the aerial armament group. figure 9 illustrates images of the assembled vehicle and the tests performed in the field.

Figure 9: Assembled Lifting Vehicle and Field Test. Own Elaboration.

Design of the ammunition transport vehicle - The transport vehicle, as its name indicates, is only used in the transportation and location of the ammunition to the protection zone of the aircraft. At this point, the transfer of ammunition to the handling or lifting vehicle must be done in order to facilitate the task of installing the ammunition in the aircraft. A preliminary sketch of the equipment transport vehicle is illustrated in figure 10.

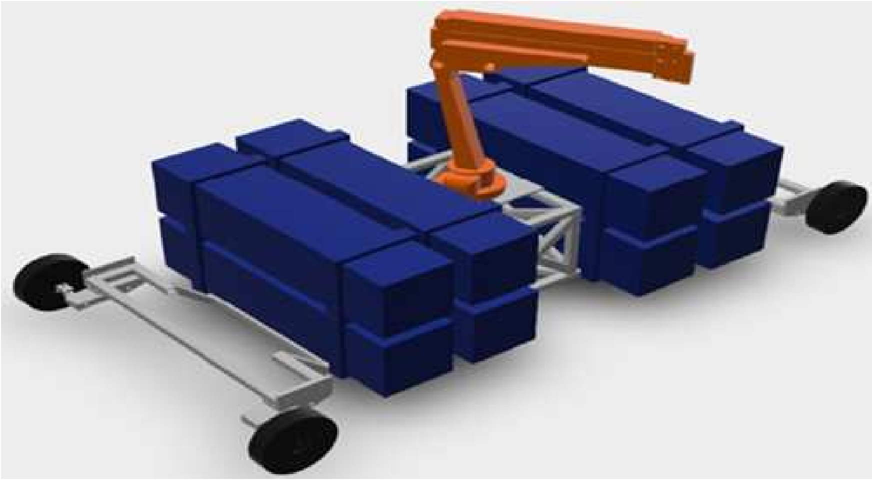

Figure 10: Preliminary Sketch of the Transport Vehicle. Own Elaboration.

To define the characteristics of this vehicle and to review the current procedure and perform the analysis of times and movements linked to their risks, several tasks were carried out with the officers staff and non-commissioned officers of the aerial armament squadron.

Within the design process, operating conditions were evaluated in order to estimate possible risks associated with the rollover of the vehicle under operating conditions. An analysis of dimensions and operation is illustrated in figure 11.

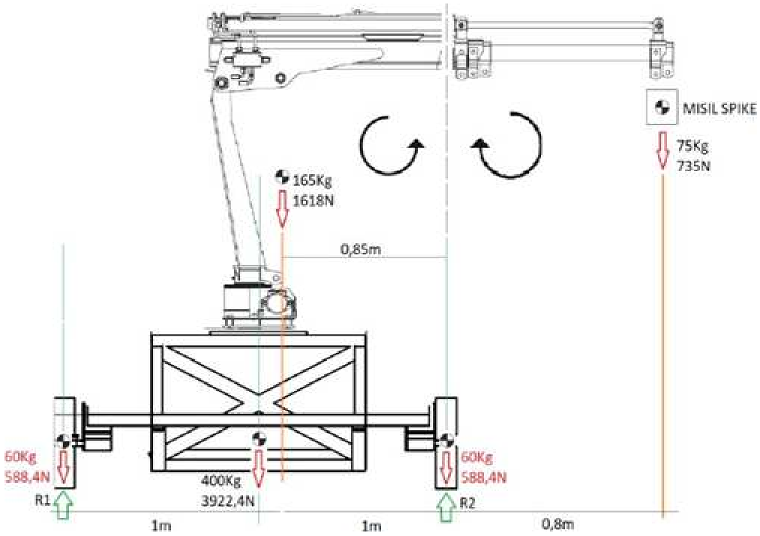

Figure 11: Rollover Calculus of the Transport Vehicle. Own Elaboration.

Once the task and validation process was carried out by the CACOM 5 staff, the CAD designs of the system was simulated in order to perform the software validation of the strain and stresses static calculation, which allowed to define the design criteria such as materials, thicknesses, manufacturing processes and other relevant aspects in the manufacture of the equipment.

The Finite Element Analysis (FEA) process - FEA, was carried out using modern mesh techniques of different sizes and with the appropriate border restrictions. The results allowed predicting the static behavior of the metallic structures as is illustrated in figure 12.

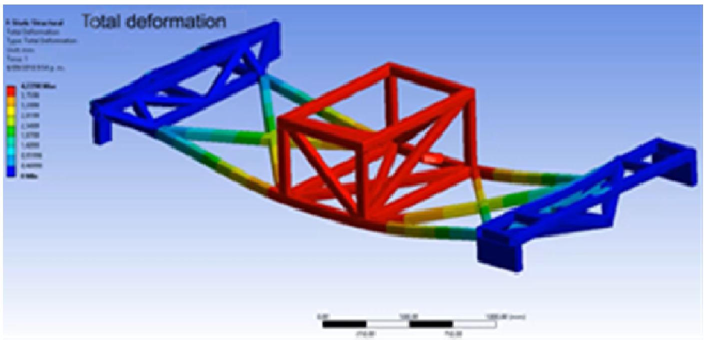

Figure 12: Deformation calculus of the Transport Vehicle structure Own Elaboration.

The analysis of the structure simulation results identified a Numerical Singularity; This singularity could appear in most of the problems of three-dimensional fracture under elastic behavior; better known as corner or free edge singularity, located at the intersection of the crack front with a free border. However, its effect is usually ignored since its zone of influence is small in relation to the area of influence of the singularity of the crack front [10, 11, 13].

Figure 13: Design and Manufacturing of the Ammunition Transport Vehicle Own Elaboration.

CONCLUSIONS

- The process of installing weapon systems requires intense physical activity by technical personnel. This requirement generates muscular fatigue which directly influences the risks of both the personnel and the manipulated equipment, since it increases the probability that the equipment will suffer blows that generate damage to the structure of the armament or its operation.

- After the research, it can be concluded that the United States is the country with the most technological research and development around equipment for the transportation of ammunition; which are patented, registered and developed since 2007. At the date of consultation, 901 patents had been registered in the United States, followed by the United Kingdom with 229 patents.

- In addition, the main manufacturers were identified worldwide, which indicates that the leading companies in the development of this type of technology are: BOEING COMPANY as the leading entity in this sec- tor worldwide, followed by Raytheon Company, the Naval Secretariat of United States, the SAAB Multi- national and Lockheed Martin.
- One of the most relevant aspects identified in the technological surveillance is that worldwide specialized equipment is used for the transport, handling and lifting of ammunition that will be installed on aircraft, eliminating to the minimum the manual handling of the above mentioned ammunitions.
- Likewise, equipment specifically designed to locate amunitions on specific aircraft or equipment configured to load specific ammunitions is highlighted, the latter being an aspect defined by the ammunition manufacturer, who issues a technical document and / or installation manual with specialized equipment.
- The use of the equipment manufactured in the project (transport vehicles and arms lift), managed to reduce their handling by 90%; that is, manual intervention by technical personnel is minimal compared to the previous installation process.
- The physical risks of the technical personnel at the time of installing the armament were reduced by 95%.
- The response times of the technical personnel, when preparing and installing the armament, were reduced by 10%.
- Method and time studies, as well as the detailed installation process, cannot be published or disclosed by any means - National Defense Protocols.
- Finally, according to the recommendations collected from the different amunitions manufacturers, specialized equipment is required to minimize manual handling, and at the same time, that the equipment is configured to meet the need for location in specific aircraft, that is, a team of transport and handling for a specific type of aircraft.

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